few instances it was succeeded by greater waves. The succeeding waves maintained considerable amplitudes—not less than half the maxima values—for about twelve hours, appearing at intervals of one or two hours apart at all the more prominent stations. They were succeeded by wavelets gradually diminishing in size, but continuing for some time, being traceable on the diagrams for August 29 and 30, the second and third days after the great eruption. It is noticeable that they ceased first at Port Blair and Negapatam, the two nearest stations, and last at Aden, the farthest station.

6. Loud reports, resembling the firing of distant guns, were heard at Port Blair on August 26 and 27, and being supposed to be signals from a vessel in distress a steamer was sent out in search of the vessel; similar reports were heard on the 26th in Ceylon.

These facts show that the great eruption at Krakatoa was preceded by minor eruptions sufficiently powerful to produce effects which were sensible at a distance of upwards of 4000 miles; also that it was probably followed by minor eruptions, to the influence of which the long-protracted continuance of tidal disturbance is due.

The time at which the great eruption occurred is still not known with any precision. Major Baird has endeavoured to calculate it from the following data: he was informed by Her Majesty's Consul in Java that the first great (positive) wave reached Batavia at 12h. 10m. local time on the afternoon of August 27; as the distance from Krakatoa by sea is 105 miles, and the average depth of the sea about 186 feet, he infers from the table of the velocity of free tide waves passing over seas of different depths, in Sir George Airy's article on "Tides and Waves" in the *Encyclopedia Metropolitana*, that the wave must have taken about two hours to reach Batavia, and therefore that it must have started at 10.5 a.m. Krakatoa time, allowing five minutes for the difference of longitude. Another estimate has been recently furnished by General Strachey in a paper—read before the Royal Society—on the "Barometrical Disturbances which passed over Europe between August 27 and 31"; General Strachey connects these disturbances with the great eruption at Krakatoa, and infers, from the recorded evidence of the times of transit of the barometric waves over the European observatories, that the initial barometric rise occurred at 9h. 24m. Krakatoa time on the morning of August 27. Now we have seen that the first effect of the great eruption on the ocean was the production of a negative wave which preceded the great positive wave by an interval of seventy-five minutes at Negapatam, and twenty-four minutes at Aden; if then we assume that the interval was somewhat more than seventy-five minutes at Krakatoa itself—as is to be inferred from the fact that wherever registered it increases as the distance from the centre of impulse diminishes—General Strachey's and Major Baird's determinations will be seen to corroborate each other very closely; indeed, considering the absolute independence of the two methods of deduction, the facts of observation being in one instance derived from the atmosphere, in the other from the ocean, the coincidence between the results is very striking.

Major Baird has calculated the velocities with which the great positive wave travelled from Krakatoa to the more important of his own stations, and also to Port Louis in the Mauritius, and Port Elizabeth in South Africa.[1] Starting with the assumption that the wave left Krakatoa at 10·5 a.m., August 27, local time, he finds that it attained its maximum value, 467 statute miles per hour, in transit to both Port Louis and Port Elizabeth. Considerable interest attaches to this determination, in that it is identical with Sir George Airy's tabulated value of the velocity of a free tide-wave passing over an ocean 15,000 feet deep, which is supposed to be the average depth of the ocean in this direction; moreover, the fact that the same velocity is obtained for both the ports, and that the nearer of the two is only 3400 miles from Krakatoa, while the other port is 5450 miles distant, indicates that there is probably no material error in Major Baird's adopted time of starting. The velocity of the wave in all other directions is less, viz. to Galle 397 miles, to Negapatam 355 miles, and to Aden 371 miles. The velocities are necessarily computed on the assumption of a uniform rate of progress from the origin to the point reached; but each of the slower waves must have coincided with the wave which impinged on Ports Louis and Elizabeth for a considerable distance in the early portion of its course, and it must then have travelled with the same high velocity; afterwards, on passing over shallower seas, the velocity must have much diminished, and very possibly it may have fallen to the smaller velocity values which Major Rogers has calculated for the sea-waves in the Bay of Bengal, on the occurrence of the earthquake of December 31, 1881.

The Admiralty chart of the Eastern Archipelago shows that Krakatoa is situated at the focus of what may be regarded as a parabolic figure, formed by the contiguous portions of the coasts of Java and Sumatra; the axis of the figure is directed towards the Indian Ocean. Thus the waves generated by an eruption at Krakatoa would be mostly propelled towards that ocean, both directly and by reflection from the coasts; but near the apex of the parabola there is an opening, the Straits of Sunda, through which a great wave passed, carrying widespread destruction for some distance beyond along the contiguous coasts. This wave may have impinged with great force on the south-west corner of the Island of Borneo, which is on the prolongation of a straight line drawn from Krakatoa through the Straits. But it did not reach Singapore, where a tide-gauge is established, and which is within a third of the distance of the nearest Indian station from Krakatoa; the Master-Attendant at Singapore reports that the gauge shows "no difference whatever in the tide." This is obviously due to the fact that the wave which passed through the Straits of Sunda had but a shallow sea to advance over towards Singapore, and its course must have been greatly impeded by numerous islands and shoals and the narrow straits and passages between them. For similar reasons, and because the axis of the parabola in which Krakatoa is situated is pointed towards the Indian Ocean, it is probable that the effects of the eruptions were not conveyed to anything like so great a distance along the numerous groups of islands to the east and into the Pacific Ocean.

J. T. WALKER

[1] For these ports he employs the data published in NATURE, vol. xxviii. p. 626.

THE INDIAN SURVEY[1]

THIS is the fifth report of the amalgamated Department of Surveys under the Government of India. It is divided into two parts with an appendix. Part I. gives a summary of the operations of the great trigonometrical, the topographical, and revenue survey parties; also of the geographical, geodetic, and tidal, and levelling operations. Part II. describes the operations at the Head-Quarters Offices, viz. the Surveyor-General's Office, the Revenue Survey Office, the Lithographic Office, the Photographic Office, and the Mathematical Instrument Department, all in Calcutta; and of the Trigonometrical Survey Office in Dehra Dun. Index charts, coloured maps, and sketches showing the present state of this very important department accompany this report; to which is prefixed, as frontispiece, a "Specimen of *Heliogravure* by Major Waterhouse's Process," which invites the

[1] "General Report on the Operations of the Survey of India during the year 1881-82." Prepared under the superintendence of Lieut.-General J. T. Walker, C.B., R.E., F.R.S., &c., Surveyor-General of India. (Calcutta, 1883.)

special attention of photographers and engravers. An appendix, separately paged, of 120 pages, completes the volume, and consists of extracts from the narrative report of the executive officers in charge of the survey parties and operations.

This report is distinguished from previous ones by announcing the completion of the great triangulation on the lines originally marked out in 1830 by Col. Everest, which affords the Surveyor-General, in his introductory statement, an opportunity of giving a brief but interesting history of this great undertaking from its commencement in the year 1800, in Southern India, by Major Lambton, on the recommendation of the Hon. Col. Wellesley, afterwards the Duke of Wellington. The object of this so-called "Mathematical and Geographical Survey" was then stated to be "to determine the exact positions of all the great objects best calculated to become permanent geographical marks to be hereafter guides for facilitating a general survey of the peninsula," and further, that in the interests of general science it would have to be executed with the utmost possible precision, and be supplemented by astronomical determinations of position, with a view to the requirements of geodesy.

The operations between the years 1800 and 1825 may be briefly described as consisting of a network of triangulation over Southern India, and through the middle of which a principal chain of triangles was carried in a meridional direction from Cape Comorin up to Sironj in Central India. This chain forms that which is now known as Lambton and Everest's Great Arc. Col. Lambton died in 1823, and was succeeded by Col. Everest, who, two years afterwards, proceeded to Europe, spending four years in supervising the construction of new instruments—great theodolites, astronomical circles, standards of length, and compensation bars for base-line measurements, for employment in extending and revising the Great Arc, the importance of which was recognised by all men of science in Europe.

Returning to India in 1830, Col. Everest recommended the abandonment of the network system of triangulation and the substitution instead of what he called the "gridiron" system, consisting of meridional chains of triangles tied together at their upper and lower extremities by longitudinal chains. The meridional chains were to be constructed at intervals of about one degree apart, while longitudinal chains would follow the parallels of Calcutta, Bombay, and Madras, and thus run at intervals of from five to six degrees apart. The external chains of the gridiron would of course follow the British frontier lines and the coast lines, and all grounded on ten base lines measured with the Colby apparatus of compensation bars and microscopes. This programme of operations was approved by the Government of India and Court of Directors, and has furnished the guiding lines on which the principal triangulation has been executed during the period of almost exactly fifty years which has since elapsed. For geodetic purposes, the amount of principal triangulation is now ample. Outside the limits of India proper, the recently completed chain of principal triangles, called the eastern frontier series, is a valuable contribution to geodesy and geography.

Thus the great work of the principal triangulation of India is now an accomplished fact. Commenced in 1800, under the auspices of the Madras Government, it was carried on, almost alone, by Major Lambton, until 1818, when the Marquis of Hastings, then Governor-General, placed it under the control of the supreme Government, and Capt. Everest was appointed assistant to Major Lambton. In 1832 additional officers were appointed, and by the year 1840, when the northern section of the Great Arc was completed, the *personnel* sufficed for the equipment of six triangulation survey parties, which number has been uniformly maintained from that time onwards until gradually diminished on the completion of the successive chains of triangles. The operations have been uniformly and consistently supported by successive Governments of India with equal liberality and constancy, and to whom it must be a source of much satisfaction to know that this great work of permanent peaceful usefulness will assuredly take the highest rank as a work of scientific labour and skill.

It is stated that there are 3472 principal stations. On the plains they are constructed in the form of towers, rising from 20 to 40 and even 60 feet above the ground, and usually about 16 feet square at base, with an isolated central pillar for the instruments to rest on. On hills and mounds and other eminences the central pillar, always of masonry, is raised 2 to 4 feet above the ground level, and is surrounded with a platform of earth and stones. Mark-stones, engraved with circle and central dot to define precisely the station point of observation, are inserted at the surface and at the base of the pillar. The stations, scattered over 338 British districts and native states, are placed under the protection of local officials, each of whom is required to send annual reports of the condition of the stations within his district. Repairs are effected when necessary, and if so maintained by future generations of officials, the duration of the stations should be coeval with the hills and plains on which they stand, and be of lasting utility.

The field operations of measurements of base-lines and angles of the principal triangulation being completed, the simultaneous reduction of the vast number of such facts, acquired over all India, by many individuals and during a period of many years, to a harmonious whole, was obviously impossible. Thus it became necessary to divide the triangulation of India proper into five sections; and even then the simultaneous reduction of the numerous facts of observation collected together in each group was a work of enormous labour, necessitating, as stated by the most eminent living authority (Col. Clarke, C.B., *Geodesy*, p. 257), "the most elaborate calculations that have ever been undertaken for the reduction of triangulation by the method of least squares." The final results of the first section are given in vols. ii., iii., and iv. of the "Account of the Operations of the Great Trigonometrical Survey of India," published in 1879 (vol. i. is devoted to base-lines, and vol. v. to pendulum operations); those of the second section in vol. vi., published in 1880, and those of the third in vols. vii. and viii. will be shortly published. The simultaneous reduction of the fourth section is now completed. The final reduction of the last section has not yet commenced, nor has the recently completed eastern frontier series.

The requirements of geodesy necessitate astronomical observations for the determination of latitude and azimuth and electro-telegraphic observations for the determination of differences of longitude at several stations of the principal triangulation. These have already been completed to a considerable extent; and further operations of this nature are in progress by two small astronomical parties attached to the geodetic branch of the department, and by whom all the operations subservient to geodetic science should be completed in the course of a few years. An extensive series of pendulum observations for investigations of gravity and the figure of the earth, taken chiefly at stations of the principal triangulation, has been completed and connected with the groups of corresponding observations in other parts of the globe. Long lines of spirit levels have been, and are still being carried on in connection with the principal triangulation, from the sea to the base-lines in the interior, and from sea to sea across the peninsula; they rest on determinations of the mean sea level, which have been and are being made at tidal stations on the coasts, and which promise to furnish most important data by means of which our knowledge of the constitution of the earth's mass may be extended.

Reference can only be here made to the report for most

interesting information as to the progress of the thirteen topographical parties, the two *Mouzawar*, or village survey parties, and the six cadastral or field survey parties, whose duties now include, as an experiment, the reecording of particulars about each field; thus reducing the cost of preparing the "Record of Rights" for the Board of Revenue. The geographical reconnaissance and trans-Himalayan explorations are replete with curious information to every student of nature, and of the habits and customs of the frontier hill tribes and peoples. The perusal of this report increases, if possible, our good opinion of the skill and devotion to duty of the several officers, and of the marked ability of the administration of this department by General Walker, and which it is most pleasing to find so handsomely acknowledged by the Government of India.

ZOOLOGY AND BOTANY OF ALASKA[1]

THE United States Revenue cutter *Corwin* went on a cruise in 1881 to Alaska and the Arctic Ocean. The main object of the voyage was to search the various accessible portions of the Arctic coasts for traces of the *Jeannette* and two missing whaling vessels which were lost the same season that the *Jeannette* entered the ice. Leaving St. Michael's on June 21, Behring's Sea was crossed to St. Lawrence Island and Plover Bay on the Siberian coast; then the *Corwin* went along this coast through the Straits and north-west to the vicinity of Nordenskjöld's winter quarters, where a sledge party, which had been left there earlier in the season to search the coast in that district, was taken on board; it then returned to St. Lawrence Island and St. Michael's. After a short delay it again proceeded to the Arctic, touching at all the islands in Behring's Straits, visiting in succession the entire Alaskan coast line from Behring's Straits to Point Barrow, including Kotzebue Sound, and on the Siberian shore from the Straits to North Cape. It also cruised along the edge of the ice pack, visiting Herald and Wrangel Islands—almost unknown masses of land—and, returning homewards, some time was spent at Ounalaska in the Aleutian Islands fitting for the voyage to San Francisco, which was reached in October.

As one of the results of this cruise, we have a series of notes and memoranda, medical and anthropological, botanical and ornithological, published by order of the House of Representatives at Washington.

The medical and anthropological notes of Alaska are by Dr. Irving C. Rosse. The health of the ship's crew was fairly good throughout the voyage, very careful precautionary measures being observed: for the usual habit of deluging the decks above and below every morning with water, a system of scraping and dry scrubbing was substituted with excellent results, and the decks were only wetted once or twice a month on fine days. Good water was procured nearly everywhere in the Arctic, and it is noted as of unusual excellence at Cape Thompson and at Herald and Wrangel Islands. The weather was mostly wild, with snow and hail; in the latter part of June at St. Michael's the sun was found almost overpowering, although the thermometer registered but 60°. Dr. Rosse gives a sketch of the diseases peculiar to the aboriginal population, especially of an epidemic of pneumonia which prevailed at Ounalaska. He declares "that there is an absolute consensus of opinion both among the executive and medical officers of late Arctic expeditions in regard to the judicious use of alcoholic beverages," and that though himself of abstemious habits, yet the facts observed "warrant him in testifying to the undeniable good effects of whisky when served out to the crew after unusual fatigue and exposure." On reaching St. Lawrence Bay, Siberia, a native speaking a little English was at his own request taken on board; the bustle and stir brought on a state of sleeplessness, and his state of mind was not improved on seeing the collection of skulls on board, nor by the chaff of the forecastle men, who tried to persuade him he was to be brought to San Francisco as an anatomical curiosity. As a result he stabbed himself dangerously in the left chest, and then leaped overboard; a boat being alongside, he was promptly rescued. The knife was found to have entered several inches, and blood and air were escaping from the wound. The symptoms were such that, writes Dr. Rosse, "the patient ought to have promptly perished, notwithstanding the treatment," but in a few days the patient was landed at Plover Bay, where he recovered sufficiently to start on foot for his home over a rugged mountain way 150 miles distant. "Wounds seem to heal uncommonly well in the Arctic, a fact doubtless owing to the highly ozonised condition of the atmosphere, and the absence of disease germs and organic dust."

Dr. Rosse's anthropological notes on the natives met with are of some importance, though his conclusions based on these may not always be acceptable. Referring to the prevalence of tattooing among the Esquimaux women, he gives a figure of strange design seen on the cheeks of a woman of St. Lawrence Island. Some drawings of crania are given, but we have failed to find any detailed account of them.

The botanical notes on Alaska are by John Muir. There is no line of perpetual snow on any portion of the Arctic regions known to explorers. Every summer the snow disappears not only from the low sandy shores and boggy tundras, but also from the mountain tops; for nearly three-fourths of the year the plants lie buried under it, but they awake up in June and July to a vigorous growth, and on the drier banks and hills about Kotzebue Sound, Cape Lisbourne, and elsewhere, many species show but little climatic repression, growing during the long summer's day tall enough to wave in the wind, and to unfold a rich profusion of flowers. A list of the species found at the following localities is given—St. Michael's, Golovin Bay, Kotzebue Sound, and Cape Thompson, where a new species of Erigeron was found (*E. muirii*, Gray). On Herald Island sixteen species of flowering plants were gathered. At Wrangel Island, from an area of about half a square mile, twenty-seven species of flowering plants were collected; they all occurred in separate tufts, leaving the ground between them bare and raw as that of a newly ploughed field. Some portions of the coast, however, farther south, presented a greenish hue, as seen from the ship, at a distance of eight or ten miles, owing no doubt to vegetation growing under less unfavourable conditions than at the point the *Corwin* touched at.

The birds of Behring's Sea and the Arctic Ocean are described by Mr. E. W. Nelson; many of the breeding quarters of North American birds are given, and details are also added of some of the rarer forms met with. A fine adult male Siberian Wagtail (*Motacilla ocularis*, Swinhoe) was taken at Plover Bay the last day of June; it was in perfect breeding plumage. A specimen of *Lanius cristatus* was picked up dead on Wrangel Island. Strictly an Asiatic bird, it must have reached this distant spot during some storm, and died of starvation or exposure. A fine adult female, in breeding plumage, of *Eurinorhynchus pygmæus*, was taken at Plover Bay, and several others were seen. A specimen of *Rhodostethia rosea* in immature plumage was obtained at St. Michael's, and reference is made to three fine specimens secured by Mr. Newcomb during the drift of the *Jeannette*, which are now in the Smithsonian collection, one of which still retains its extremely rich peach-blossom pink so characteristic of this the most beautiful of the gulls.

[1] "Cruise of the Revenue Steamer *Corwin* in Alaska and the North-West Arctic Ocean in 1881. Notes and Memoranda, Medical and Anthropological, Botanical and Ornithological." (Washington: Government Printing Office, 1883.)